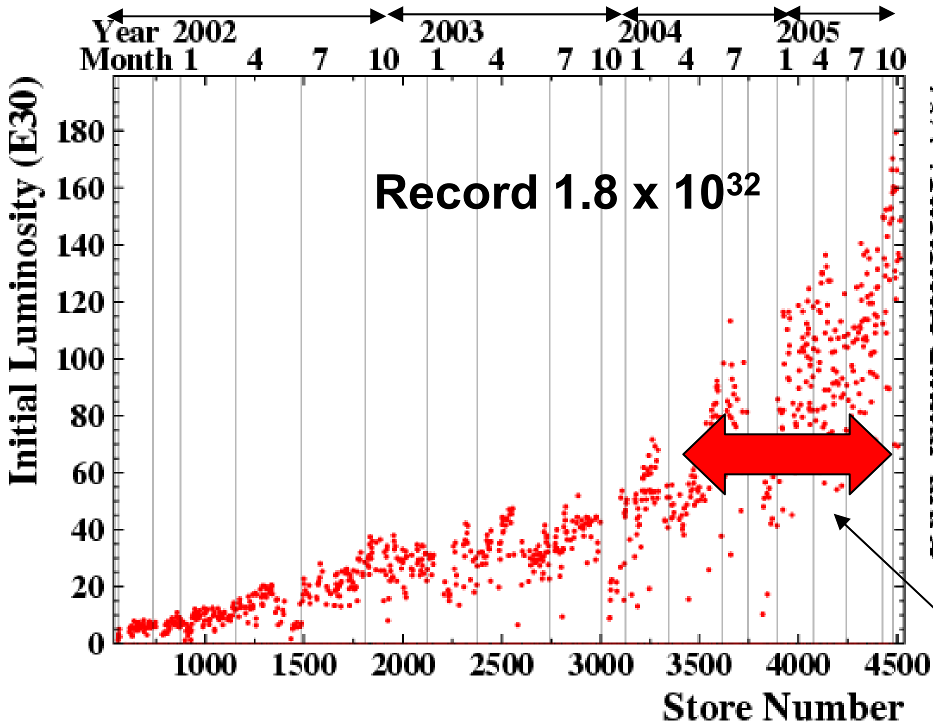
The Challenge of High Luminosity and Shrinking Resources

Young-Kee Kim and Rob Roser
For the CDF Collaboration

Detector Operations

Data Taking Efficiencies

Initial Luminosity (10^{30} cm^{-2}s^{-1})

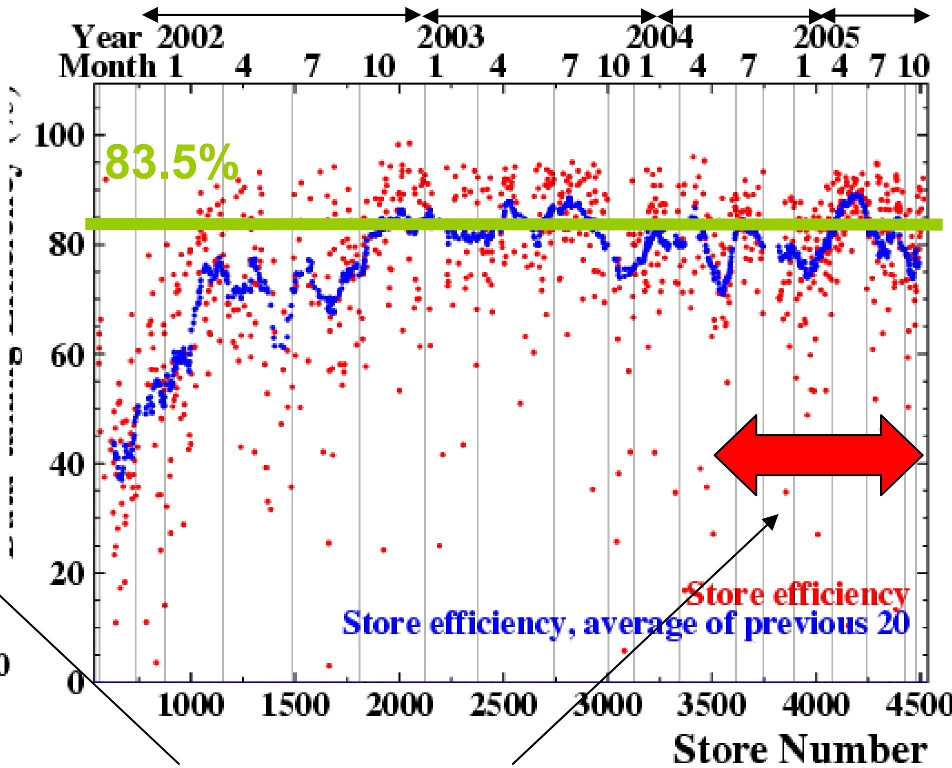


Data Taking Efficiency(%)

Detector/trigger/DAQ downtime ~5%

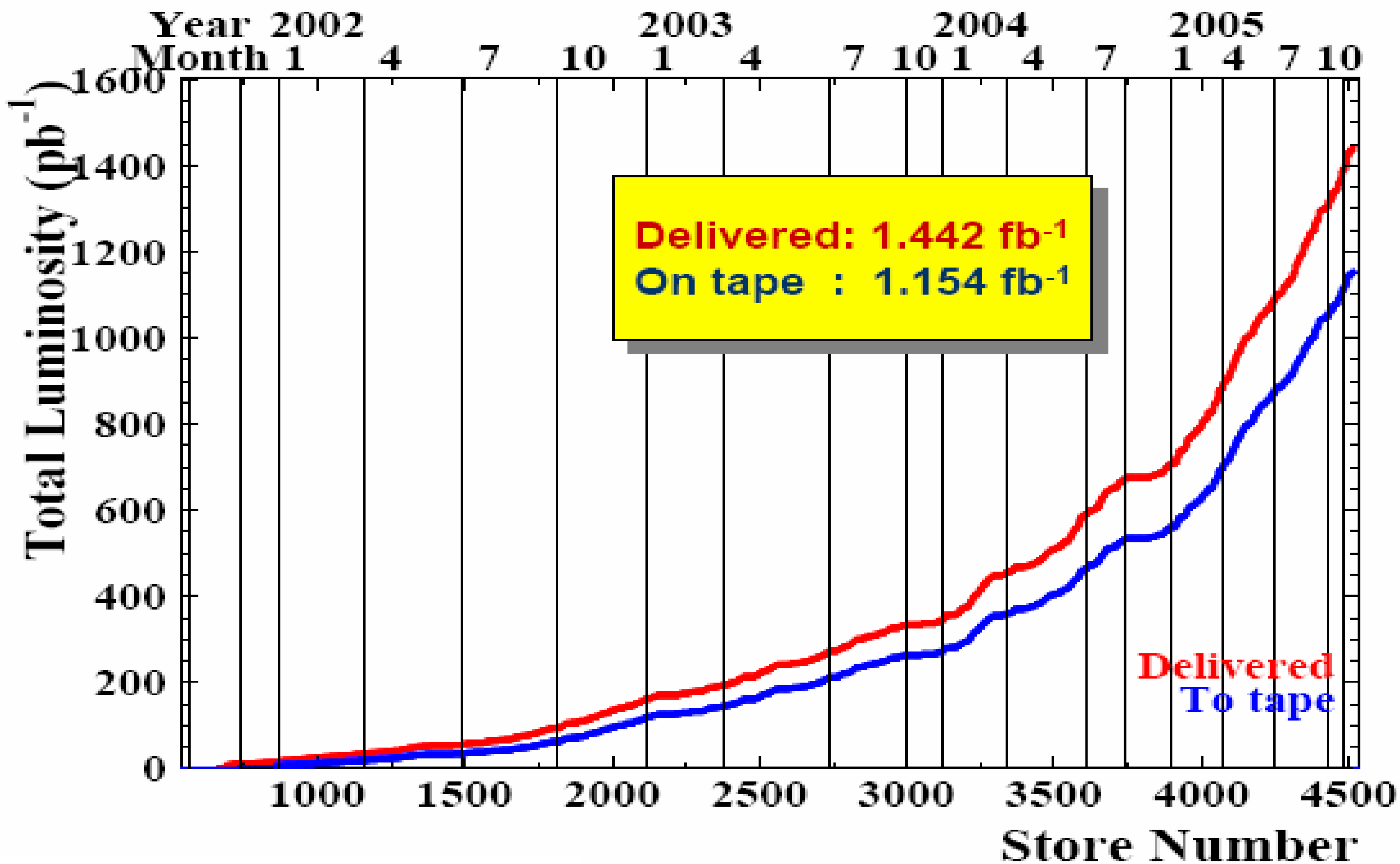
Beam Conditions, Start/end stores ~5%

Trigger deadtime ~5%: our choice



~85% of Run IIb Upgrade Projects were commissioned with beam during this period.

Data for Physics



Data up to Aug. 2004

Recorded: 530 pb^{-1}

Physics: 320 - 470 pb^{-1}

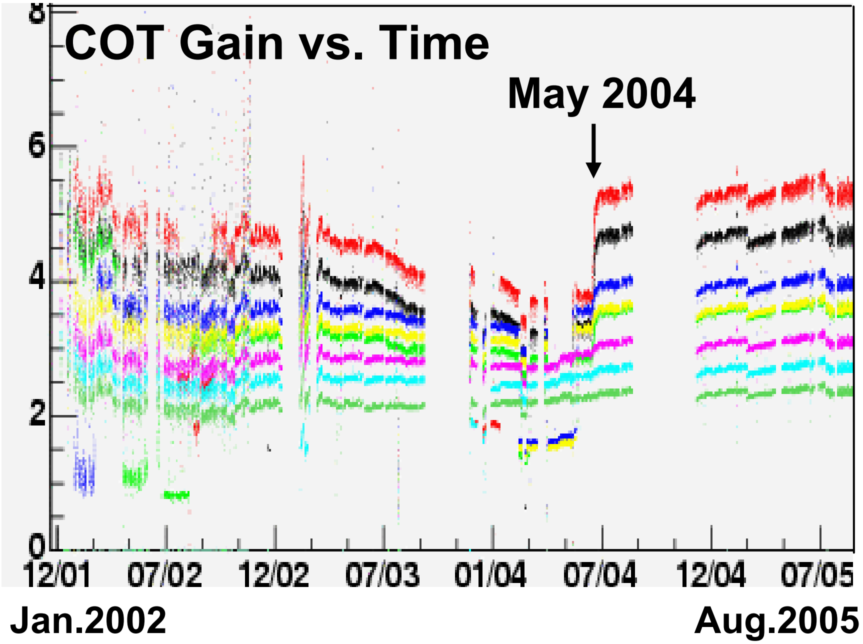
Data up to now

Recorded: 1,154 pb^{-1}

Physics: 800 ~ 1060 pb^{-1}

Tracking Systems: COT and Silicon

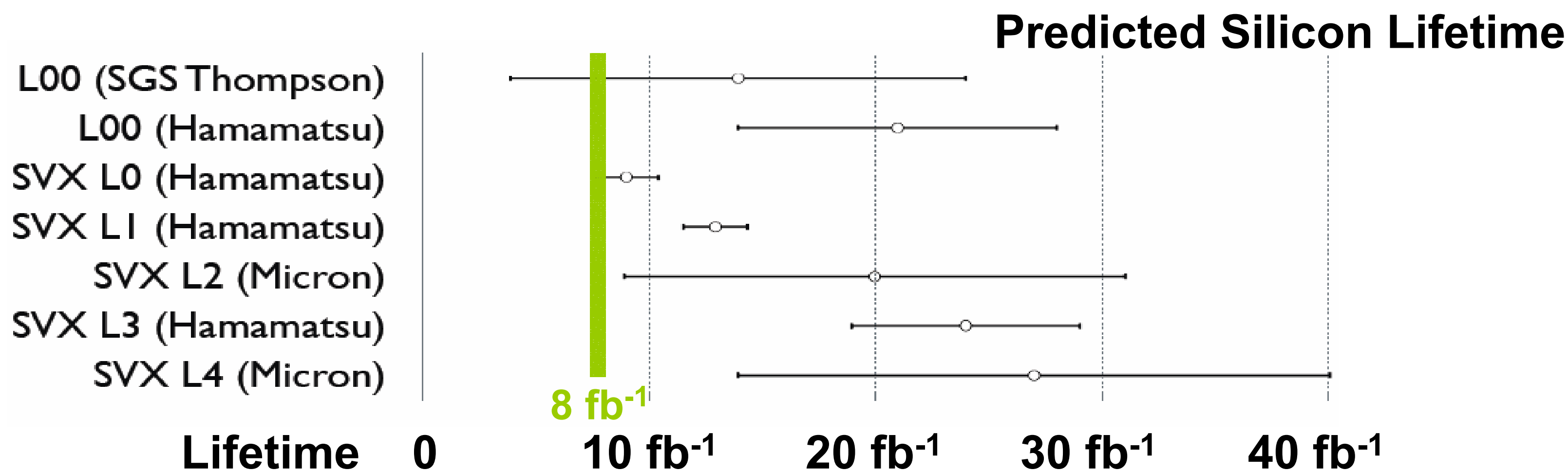
- COT Aging - Fully Recovered
  - Aging due to hydrocarbons coating sense wires
  - Fixed by adding Oxygen
  - Fully recovered May 2004
  - 99.7% working!



- Silicon detector lifetime is a complex issue involving
  - Component failures
    - ~93% powered; ~84% working + 4% recoverable in offline
    - Secondary vertex trigger requires 4 layers: 21 out of 24 wedges
  - Beam incidents
    - lost ~2% of chips: conditions improved, but still concern
  - Long-term radiation damage

Silicon Detectors

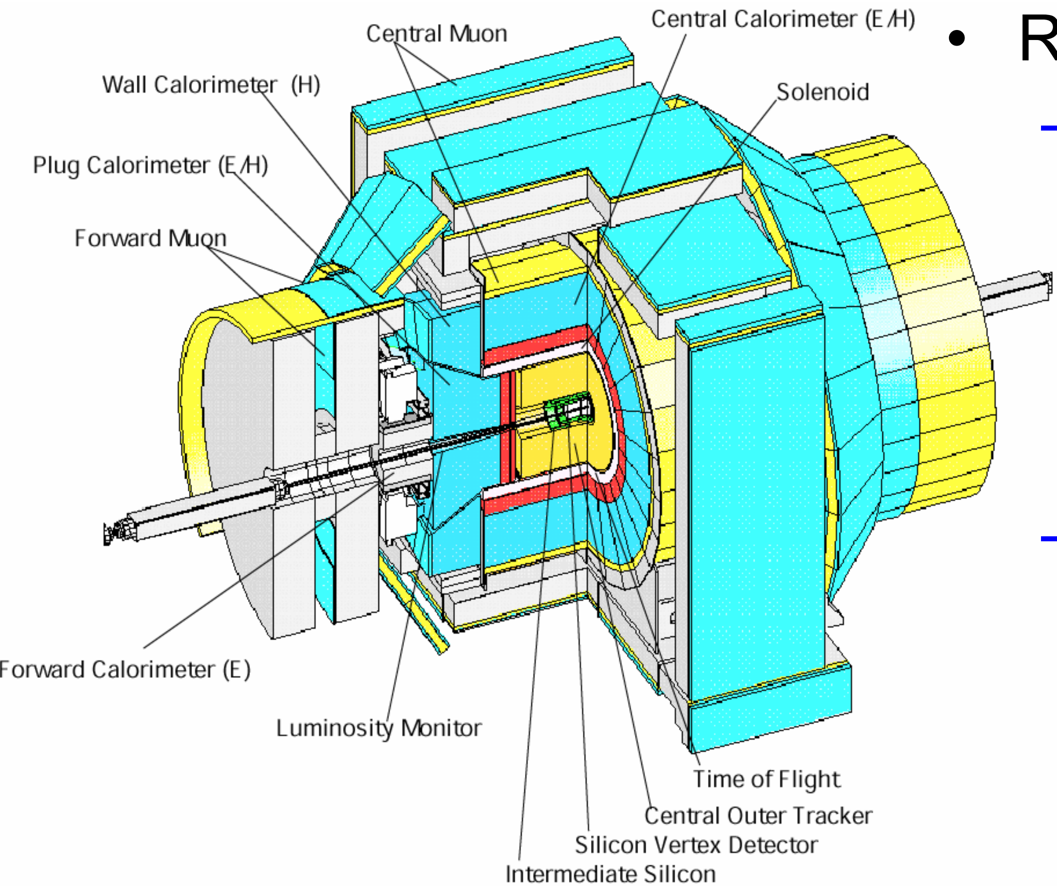
- Radiation damage
  - > 90% of total radiation is due to collisions: NIM A514, 188-193 (2003)
  - Bias voltage scans as luminosity accumulates
    - Study collected charge (hits on tracks) and mean noise
    - Measurements agree with predictions up to 1 fb^{-1}.



- Efforts to increase the Silicon lifetime
  - Lowered Silicon operating temp. gradually from -6°C to -10°C.
  - Thermally isolated SVX from COT inert regions such that the silicon can be kept cold during COT work.

Detector Upgrades

CDF Detectors



- Run IIb Upgrades: Complete
  - Central Preshower Detector
    - Replacing with a finer segmentation system
    - Electron tagger, γ/π^o separation
    - Installed fall 2004
  - Electromagnetic Timing
    - New system for rejecting beam-halo and cosmic ray
    - Searches with γ (e.g. GMSB SUSY, long-lived particles)
    - Installed fall 2004

Performing very well.
Even Run IIb Detectors! - Operational since early 2005

For the future, tracking systems are our main concerns.

Run IIb Trigger / DAQ Upgrades

- Instantaneous Luminosity: 2 x 10^{32} $cm^{-2}s^{-1}$ (IIa) $\rightarrow$ 3 x 10^{32} $cm^{-2}s^{-1}$ (IIb)
  - Ave # of interactions = 10, more hits / event
- Level-1: Tracking Triggers
  - low p_T tracks + hits from extra interactions $\rightarrow$ mimic high p_T tracks
  - Lower purity $\rightarrow$ higher Level-1 trigger rate
  - Upgrade: 2D to 3D tracking $\rightarrow$ high purity and lower rate
- Level-2: Decision System and Secondary Vertex Trigger
  - Upgrade: Lower processing time $\rightarrow$ higher bandwidth, more flexible
- DAQ, Level-3 computing, Data Logging:
  - Upgrade: higher bandwidth + event size increase

DAQ / Trigger Specifications

	Run IIa Specification	Run IIa Achieved (typical)	Run IIb Specification
Luminosity	0.9×10^{32}	1.5×10^{32}	3.0×10^{32}
Level-1 Accept	45 kHz	25 kHz *	30 kHz
Level-2 Accept	300 Hz	350 Hz	1000 Hz
Event Builder	75 MB/s	75 MB/s	500 MB/s
Level-3 Accept	75 Hz	80 Hz	100 Hz
Data Logging	20 MB/s	20 MB/s	60 MB/s
Deadtime Trigger	5%	5%	5% + 5% **

•Run IIa Level-1 Accept not achieved due to

•higher than specified Silicon Readout and Level-2 Trigger execution times.

** Assume ~5% from readout and ~5% from L2 processing

Run IIb Project Status

- Trigger and DAQ Upgrades
  - Level-1 Track Trigger (XFT):
    - Add *z* (stereo) info for 3D tracking
    - Installation complete, now in commissioning
  - COT TDC modification to achieve L2 rate of 1000 Hz (readout time)
    - 19 out of 20 crates are operational, (20th to be done next week)
  - Level 2 decision system: faster,flexible - operational since April 2005
  - Level 2 Silicon Vertex Trigger (SVT)
    - Faster - 3 step upgrade: the first 2 steps are operational.
  - Event Builder: operational since August 2005
  - Level-3 Computing Farm
    - All Hardware here, now being assembled and commissioned
  - Data Logging (20 MB/s $\rightarrow$ 60 MB/s)
    - 1st step operational (~40MB/s), complete by early 2006

Installation & commissioning parasitically with minimal impact on operations.

Run IIb Upgrade Status

- Very successful so far:
  - 90% complete
  - Will finish by early 2006

- Upgrade success due to:
  - Highly successful Run IIa detector/trigger design & operation
  - Carefully targeted to specific high luminosity needs
  - This allowed for incremental and parasitic implementation and commissioning with minimal impact on operations.
  - Some cases (e.g. COT TDC), instead of building new detectors, we gradually improved the systems.

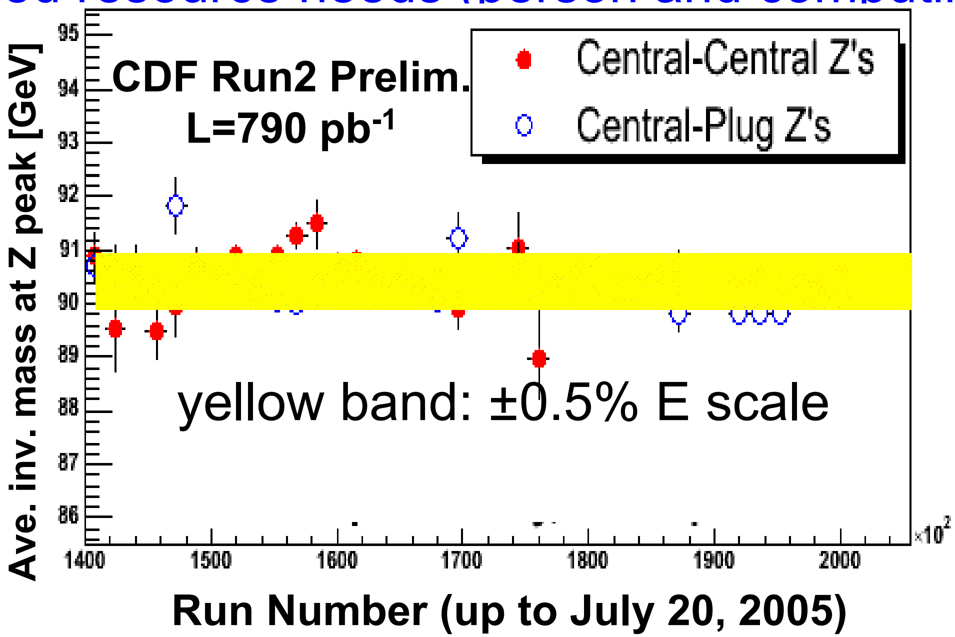
Offline Status

Offline Analysis Goals

- Goals
  - Enable physicists to complete their physics analysis this spring utilizing 1 fb^{-1} of data
    - Our “1 fb^{-1} challenge”
  - Be prepared for the 2 fb^{-1} challenge in 2007
  - Continue to improve tools and infrastructure to reduce overhead required to perform physics analysis

Data Reconstruction

- Recently achieved 6 week turn-around time between data taking and availability of physics-quality data with final calibrations.
  - This reduced resource needs (person and computing).



  - Reconstruction code has achieved a high level of physics performance and operational stability.
    - Incorporated Run II detector upgrades
    - No major changes anticipated
  - Plan to process all the data until the end of Run II at Fermilab.

Monte Carlo Simulation and Production

- Detector simulation reaching maturity - matching data
  - Incorporated detector configuration changes with time (run number)
  - Incorporated multiple interactions for data instantaneous luminosity

- Increasing access to global computing resources (GRID philosophy) to match physics needs.
  - Running on worldwide computing clusters - shared with LHC
    - ~100% of MC samples are generated outside of US.
    - Planning data analysis centers at remote sites
      - Physics analyses produced with remotely located datasets
      - Italian inst.s, Karlsruhe: J/ψ lifetime, B tagging, Single top
  - Worldwide computing resources transparent to physicists.

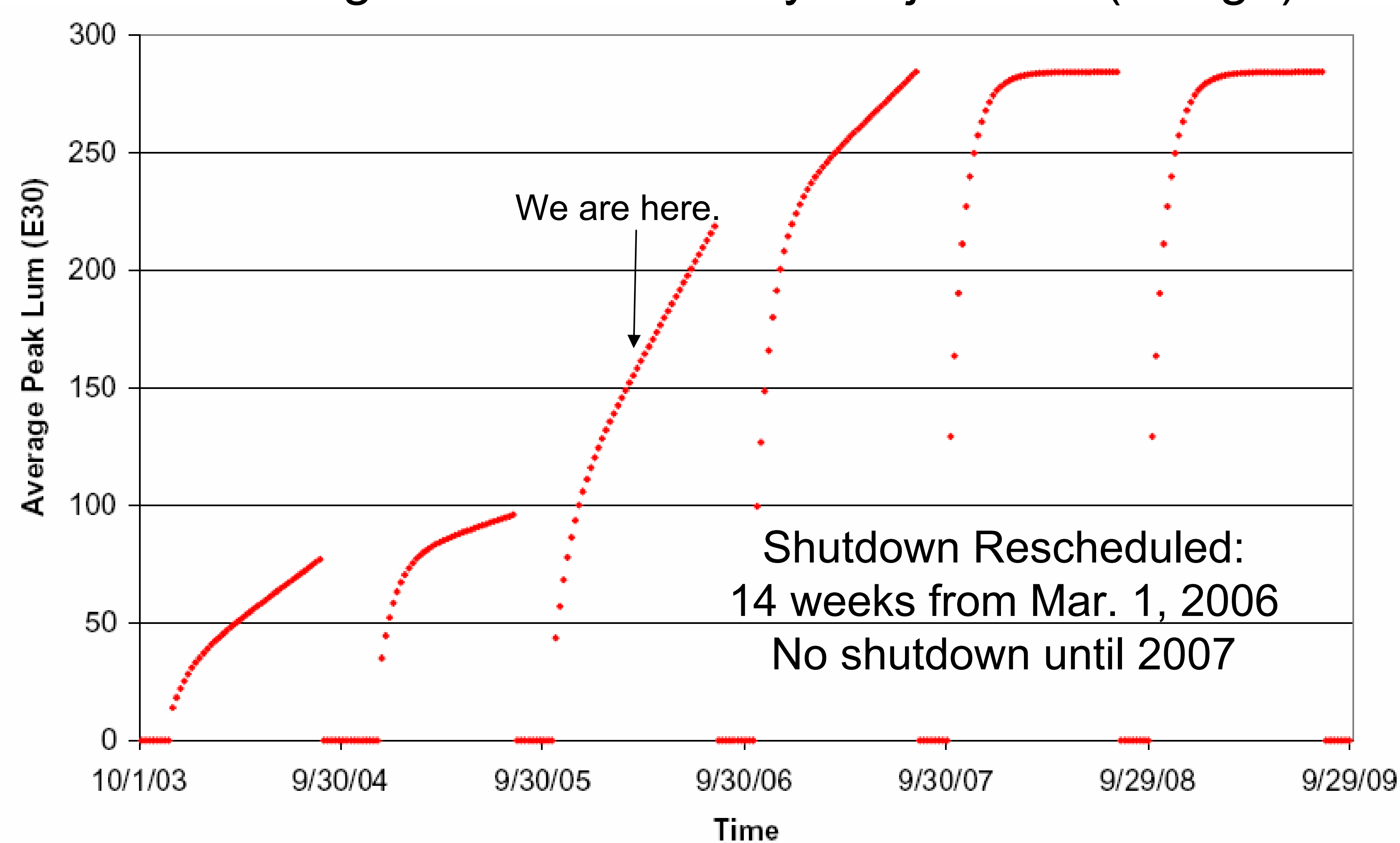
- Aim to support more computing with fewer FTEs

Preparations for the Future

Trigger

Preparation for Future

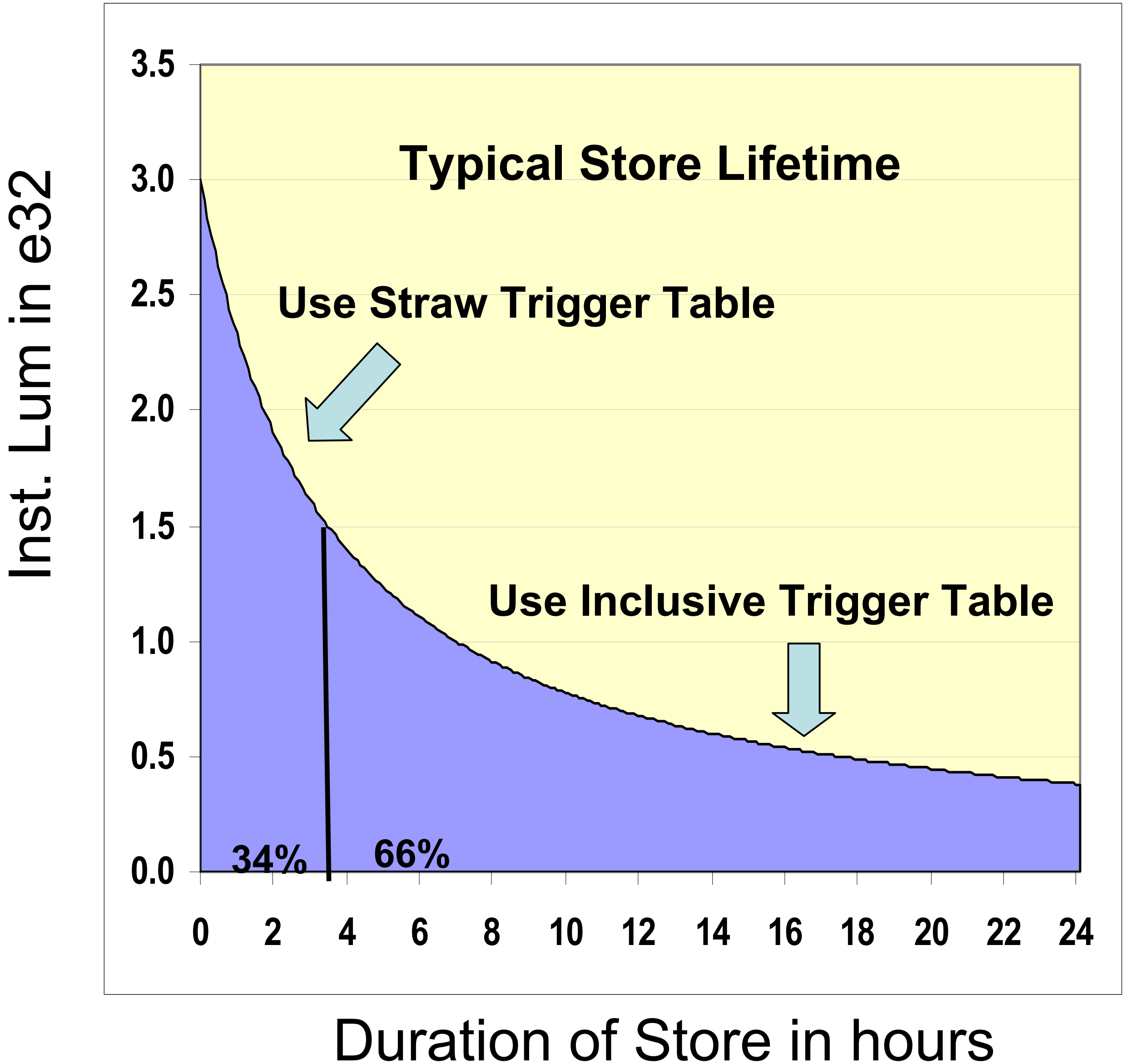
Average Peak Luminosity Projections (design)



Physics Triggers for 3 x 10^{32} $cm^{-2}s^{-1}$

- Trigger Table in current operations is good to ~1.5 x 10^{32} $cm^{-2}s^{-1}$
  - Kept improving as luminosity increases. Significant efforts!
  - Multiple interaction veto, dynamic prescales, fractional prescales, luminosity enabled triggers.
  - We make the most out of lum delivered!
- Even with all triggers/DAQ upgrades, we can not maintain an "all inclusive" trigger table for L > 1.5~2 x 10^{32} $cm^{-2}s^{-1}$
- We will be forced to sacrifice <u>some fraction</u> of our physics program at high luminosity
- Need to establish priorities based on physics goals
- Run IIb physics priorities and triggers committee formed about a year ago
  - Initially chaired by Spokespersons and now by Luciano Ristori
  - Charged with establishing a "straw" trigger table for 3e32
    - Goal is for the high pt program to occupy 50% of available bandwidth
    - Develop high purity b triggers to fill in gap at high luminosity

Physics Triggers for 3 x 10^{32} $cm^{-2}s^{-1}$



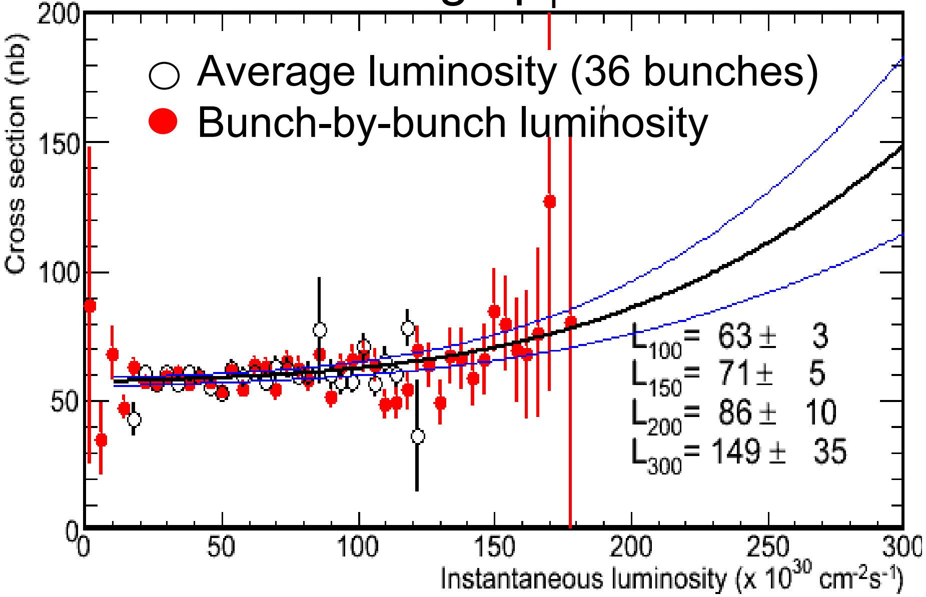
$\mathcal{L}^{peak}$ = 3 x 10^{32}

In 3.5 hours,
$\mathcal{L}$ < 1.5 x 10^{32}

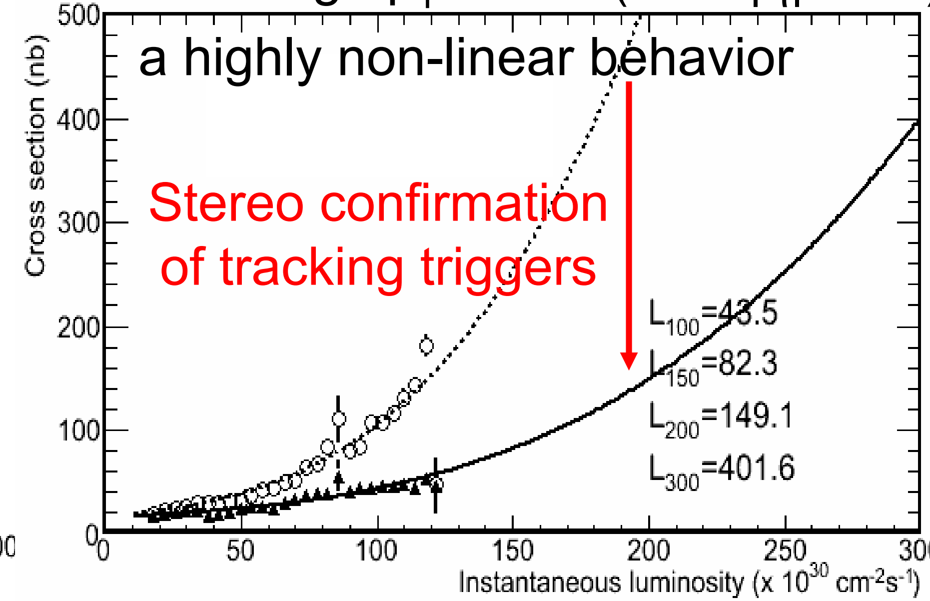
Extrapolation to 3 x 10^{32}cm^{-1}s^{-1}

- Triggers are sensitive to multiple interactions.
- Measure cross section vs # of primary interaction vertices.
- Calculate cross sec vs lum. using Poisson distribution of # of primary vertices.
- Good agreement with bunch-by-bunch data.

Level-2 high p_T electron



Level-2 high p_T muon (0.6 < |η| < 1.1)



<u>trigger rate = cross section x $\mathcal{L}$</u>

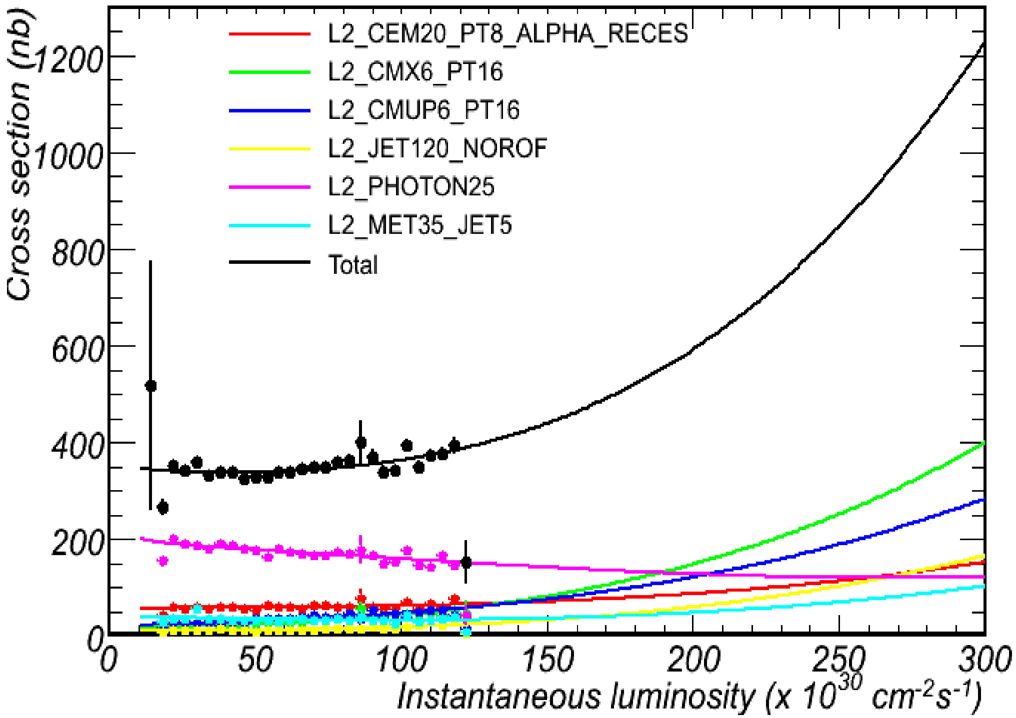
at 3 x 10^{32} cm^{-2}s^{-1}

~3% of Level-2 bandwidth

~50% of Level-2 bandwidth.
Reduce to ~10 % with XFT upgrade

Extrapolation to 3 x 10^{32}cm^{-1}s^{-1}

Cross sections of high p_T triggers (high p_T e,μ,γ,jet,$\not{E}_T$) with Level-1 upgrade
Covers W, Z, Top, WH, ZH, H$\rightarrow$WW, SUSY (partial), LED, Z'

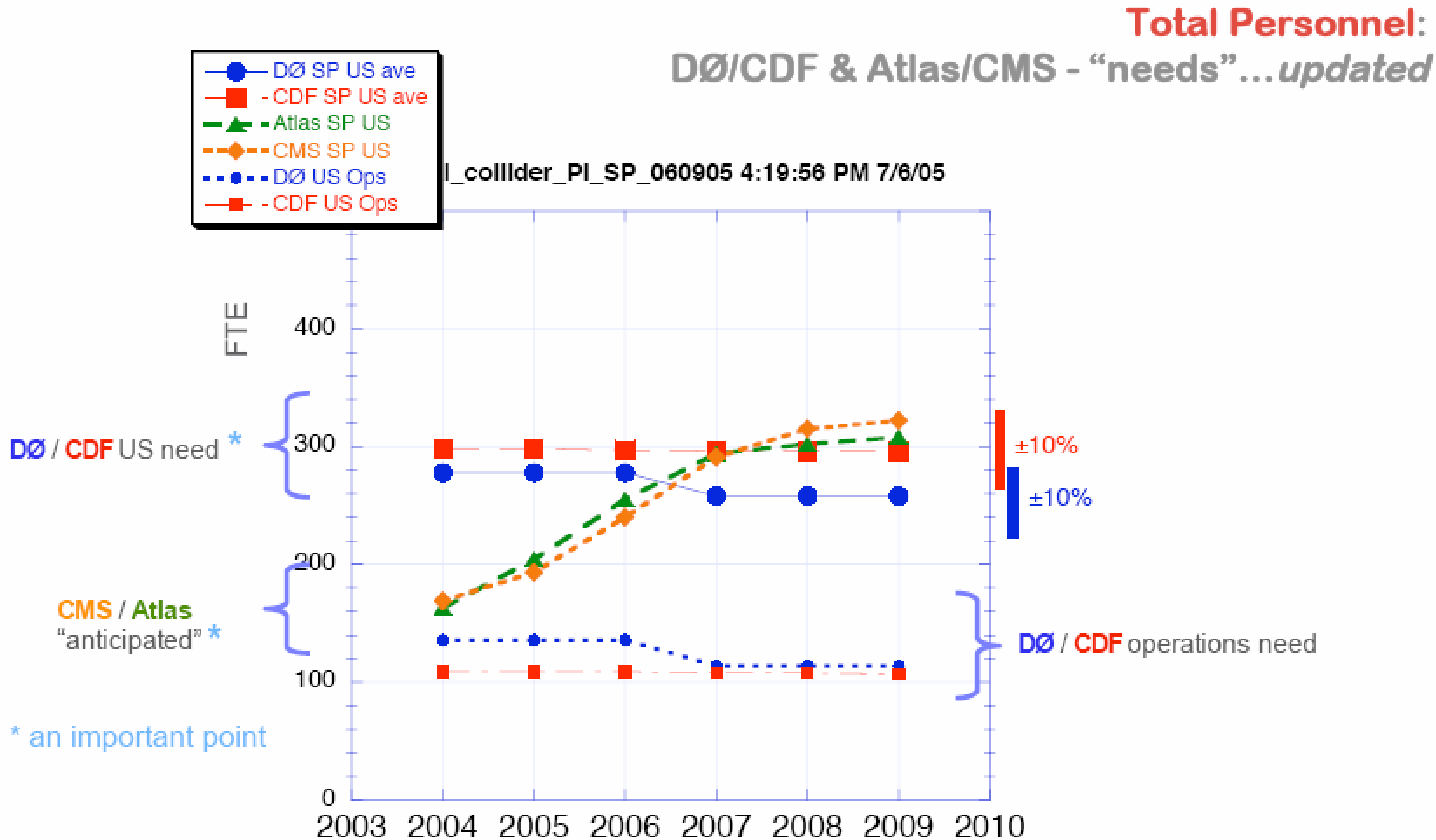


~1/3 of Level-2 bandwidth at 3x10^{32} cm^{-2}s^{-1}: studying further improvements such as track trigger upgrade to improve purity

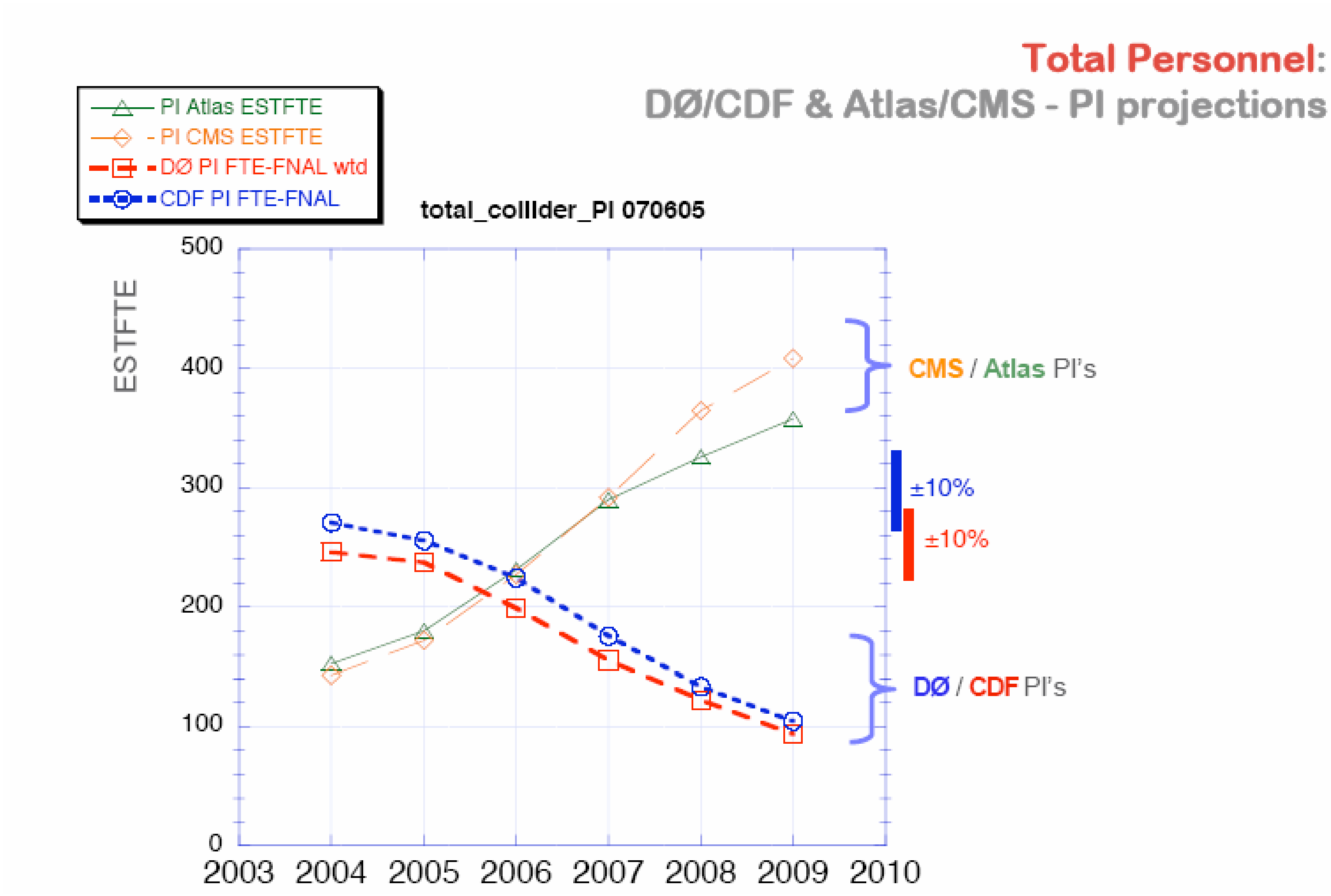
Studied triggers for "full" high p_T physics program:
~2/3 of bandwidth. Aim for 50% of bandwidth

Operating the Experiment through 2009

2004 HEPAP Survey -- Summary Plot of Needs



"The Shot Heard Round the World"



Do We Have a Problem?

- Established a joint CDF/D0/FNAL committee to understand our needs and available resources in July 2005
- Performed a bottoms up analysis of what it takes to operate the experiments and get the physics out
- Acknowledgement, that we can not operate CDF in 2008 in the identical fashion that we do now
- Divided the experiment down into 4 categories:
  - Detector Operations, Offline Operations, Algorithms/Calibrations, Core Physics Analysis
  - Core Physics -- Picked 10 physics analyses that are scientifically compelling measurements and demonstrate the potential of the collider program AND provide all tools necessary for the broader physics pgm.
    - combination of precision meas. and searches/discovery potential
    - SM and MSSM Higgs, SUSY searches, Z', LED, $B_s \Rightarrow \mu\mu$
    - Top mass, Vtb, W mass, Vtb, B_s mixing, B_s lifetime

Summary of Needs in FTE's

	2007	2009
Operations	55	55
Offline	26	20
Management	10	10
Algorithms	35	26
Total Service	126	111

FTE ≡ fraction of total working week.

NOT: fraction of research time; NOT fraction of 40 hour week!

Summary of Subgroups…(needs)

	2007	**2009**
Core Physics	*81*	*64*
Total Service	126	111
Core+Service	207	175

Results of Institutional Survey by Country

	2005	2006	2007	2008	2009
U.S.	242.8	221.2	176.6	110.2	82.8
Spain	11.8	13.2	8.7	7.7	7.7
Italy	63.4	59.7	52.2	42.2	41.6
Canada	15.7	15.8	9.3	5.1	2.1
Switz.	6.6	4.1	3.1	2	2
Germany	15	10.6	7.9	4.8	2.6
Russia	0.6	2	2	0	0
Korea	12.9	9.9	9.5	9.5	9.5
U.K.	26.5	25.5	18.3	10.6	5.2
Japan	21.7	18.2	17	13.3	8.8

In FTE's

Comparison of FTE availability and needs: 2007

Assumes people spend 50% of time on "service" and 50% doing "physics"

"Service"	126
"Core" physics	86
Total needs 1: **(service*2)**	252
Total needs 2: **(service+"core physics")**	207
Available FTE	304
Available-needs 1:	52
Available-needs 2:	97

Sufficient effort to operate experiments and support a broad physics program

Gap Analysis for 2009

Calculated from 2007 MOU FTEs using HEPAP ratio for 2009/2007

	Expt.	CDF
Available FTEs	non-US	75
	US	116
	all.expt	191
Needed FTEs	1: service*2	222
	2: service+core physics	175
Available -needed FTEs	1:	-31
	2:	16

If we used the survey, Total available is 162 FTE

Concluding Remarks/Strategies

Concluding Remarks

- CDF experiment is operating well. Better than ever!
  - Typical data taking efficiencies in the mid 80%'s with increasing inst. Luminosity and Run IIb commissioning
  - All detectors are in excellent conditions
  - Stable offline software
  - Established fast calibrations, data processing scheme
  - Good detector simulation
  - MC production at remote sites
- Challenging ahead…
  - x2 higher instantaneous luminosity
  - x8 higher integrated luminosity
  - Physicist Resources going down
- CDF Strategies in preparation for the future
  - Planning ahead: we have been identifying those areas that need further development and are beginning to address them immediately. Goal is to complete the work by mid 2006.

Concluding Remarks (cont.)

- To be done by early 2006
  - Complete Run IIb upgrades (~90% currently operational)
    - Expected to be done by the end of this year.
  - Physics trigger table up to 3 x 10^{32} $cm^{-2}s^{-1}$ being prepared.
    - Goal to run physics version of Straw Table in February
  - Tuning simulation
    - Need one more iteration for analyses with L > 1 fb^{-1}
  - Calibrations and algorithms that require large resources
    - Reducing Jet energy scale uncertainty (needs one more iteration)
    - Implementing algorithms for better Jet energy resolution
    - Improving forward tracking and B tagging
  - Preparing reconstruction algorithms for high inst. Lum.
    - Tracking and B tagging
  - Work with Universities, Funding Agencies, and the Lab to insure we continue to have the resources necessary to carry on this important physics program

Backup

Results of survey: 2005-2007

	CDF		
Year	2005	2006	2007
non-US	100%	91%	74%
US	100%	91%	73%
all.expt	100%	91%	73%
HEPAP	100%	88%	69%
FTEs	434	381	304

- Fall off for both US and non-US roughly consistent with HEPAP survey

Algorithm Development

ALGORITHMS	[redacted]	CDF FY07	CDF FY09
Muon Reconstruction	[redacted]	0.5	0.5
Tracking	[redacted]	5.1	3.4
Calorimetry	[redacted]	2.2	2.2
Taus	[redacted]	1.7	0.9
Jet Energy Scale	[redacted]	4.8	2.8
b-tagging	[redacted]	2.5	1.3
Trigger	[redacted]	7.8	4.1
Simulation	[redacted]	3.0	2.7
Luminosity	[redacted]	0.3	0.2
High Level Data Handling	[redacted]	7.5	7.5
Infrastructure	[redacted]	0.0	0.0
TOTAL ALGORITHMS	[redacted]	35.4	25.6

Core Physics Analysis

		CDF	
PHYSICS	[redacted]	FY07	FY09
Bs (Mixing, Rare Decay, Lifetime)		16.0	13.0
EW(W mass)		5.0	5.0
Higgs(SM and SUSY)		17.0	15.5
New Phenomena(Trilepton,Squarks & Gluinos, Stop&Sbottom, LED, Z')		11.5	7.0
Top (Mass and Single)		17.5	11.5
Core physics management		7.0	5.0
Tevatron Combination		3.0	3.0
Godparents/Ed.Boards		4.0	4.0
TOTAL PHYSICS		81.0	64.0